NASL-PR-18

B5

DASA Subtask 03.001

Lab. Project 9400-12, Progress Report 18

Glossary of Radiometric and Photometric Concepts Used in Retinal Burn and Flashblindness Research (Definitions, Symbols and Units)

W. Derksen

N. Griff

Physical Sciences Division

U. S. NAVAL APPLIED SCIENCE LABORATORY

BROOKLYN, NEW YORK

This document has been approved for public release and sale; its distribution is unlimited.

GLOSSARY
of
RADIOMETRIC AND PHOTOMETRIC CONCEPTS USED IN RETINAL BURN AND FLASHBLINDNESS RESEARCH
(Definitions, Symbols and Units)

DASA Subtask 03.001

Lab. Project 9400-12, Progress Report 18

W. Derksen
N. Griff

23 December 1967

PHYSICAL SCIENCES DIVISION
J. M. McGreevy, Head

Approved: E. J. JEHLE
Technical Director

Approved: T. T. M'Gillicuddy
T. T. McGILLICUDDY, CAPTAIN, USN
Commanding Officer and Director

This work was funded by the Defense Atomic Support Agency, under Subtask 03.001

U.S. NAVAL APPLIED SCIENCE LABORATORY
FLUSHING AND WASHINGTON AVENUES
BROOKLYN, NEW YORK 11251

SUMMARY

Radiometric and photometric concepts, symbols, units and definitions which are employed by the Naval Applied Science Laboratory in its retinal burn and flashblindness research are given.

TABLE OF CONTENTS

ADMINISTRATIVE INFORMATION

The work described herein constitutes part of the Naval Applied Science Laboratory's programmed effort on the Effects of Thermal Radiation sponsored by the Defense Atomic Support Agency under DASA Subtask 03.001.

ACKNOWLEDGMENTS

The work reported herein was conducted under the direction of T. I. Monahan, Head, Physics Branch. H. Korbel of the Laboratory's Scientific Analysis Staff gave considerable time and effort to discussion of these concepts with the authors and thereby contributed significantly to this development.

OBJECT

The object of this report is to present the radiometric and photometric concepts, symbols, units, and definitions compiled by the Naval Applied Science Laboratory in its retinal burn and flashblindness research. The glossary may have value for other activities engaged in these areas.

INTRODUCTION

In order that experimental results be of value, they must be reported in such manner as to minimize possible ambiguities. Confusion may arise where concepts are not carefully delineated and the corresponsing units not clearly defined. Retinal burn and flashblindness research, particularly the latter, requires both radiometric and photometric concepts in order to display data in a meaningful manner. The Naval Applied Science Laboratory proposes to employ a nomenclature based on four sources: a military standard,[1] the Glossary of Terms prepared by the American Institute of Physics and used in Optics and Spectroscopy,[2] a previous glossary issued by the Laboratory,[3] and correspondence from the Air Force School of Aerospace Medicine.[4]

GLOSSARY

The radiometric and corresponding photometric concepts are defined and given alternately in Table 1 as applied to a source of radiant energy. Table 2 lists the terms as applied to the properties of a material and Table 3 lists the terms which describe the characteristics of radiant energy at the location of a receiver. In Table 4 the radiometric and related photometric terms are listed together.

Various relationships between the quantities are often used. Table 5 relates the radiometric quantities for a spherical source. Table 6 gives the relation between radiometric terms at a receiver generally and for a focussing receiver such as a camera or eye. Table 7 gives corresponding relationships for a flashblindness situation but the source terms are for a plane surface source.

DISCUSSION

"Radiant" concepts are applied to the characteristics of electromagnetic energy at all wavelengths. "Photometric" concepts refer to what is perceived as light, i.e., radiant energy that has been weighted by the standard luminosity curve. The luminosity curve is a measure of the ability of the photopic (non-dark-adapted) eye to respond to radiant energy.

The concept of luminous flux, measured in lumens, corresponds to the concepts of radiant flux, measured in watts, the definition of photometric units following from this correspondence. Specifically, the luminous flux is related to the radiant flux P as follows:

$$F = 680 \int_0^\infty P_\lambda V_\lambda \, d\lambda \text{ lumens},$$

where P_λ is expressed in watts per micron. V_λ is the weighting factor given by the standard luminosity curve, and the theoretical maximum luminous efficacy is 680 lumens per watt.[5]

When it is desired to apply the radiometric terms to the quantity at a particular wavelength the term "spectral" is used as an adjective for the concept, the Greek letter λ is used as a subscript for the symbol. The unit wavelength interval is usually one micron but other intervals may be used. A quantity in a finite wavelength interval is not properly a spectral quantity in this sense, and it is customary to refer to it as the radiometric quantity in the stated wavelength interval.

When it is desired to emphasize that all energy in the spectrum is involved or that a summation of spectral quantities has been performed, the adjective "total" is applied, as total energy, total radiance, total emissivity, total radiant exposure, etc. The term "total" is also applied to mean all of a quantity in a pulse or to indicate that a summation over a time period has been performed. The term "radiant" instead of "total" is often applied to transmittance, reflectance and absorptance and is also used to indicate a spectral summation.

When it is desirable to indicate the location of a specific quantity an adjective is employed; thus, free field, corneal, or retinal are often used to differentiate between the various irradiances or radiant exposures under consideration.

Two photometric units which have been tentatively omitted from the table of the glossary are the lambert and the troland. The lambert is a unit of luminance and the troland a unit of retinal illuminance. A perfectly diffusing white surface receiving an illuminance of one lumen cm^{-2} is said to have a luminance of one lambert. It is common, but by no means adequately justified, to omit the concept of a perfectly diffuse surface and to use the lambert to indicate a luminance of $(1/\pi)$ lumen cm^{-2} $ster^{-1}$

without specifying the source. It is felt that this ambiguity mitigates against the use of the unit, especially as there is no clear advantage to its use otherwise. See Reference 6, page 12, for a similar comment.

The troland is defined as the retinal illuminance produced by a surface having a luminance of one candela m^{-2} when the pupil area is 1 mm^2. (The candela is a unit of luminous intensity defined such that the luminance of a blackbody at the solidification temperature of platinum is 60 candelas cm^{-2}.) In specifying trolands one measures the pupil area, and the brightness of a surface in lumens cm^{-2} $ster^{-1}$, usually by a visual matching instrument, but often by a phototube device which has been calibrated in terms of the visual matching instrument. Often the basic measurements are not described and confusion arises as to the nature of the experimental quantities. The troland is a unit of convenience and is useful only in rather specialized situations. It is also difficult to convert trolands to other photometric units in many situations of interest.

FUTURE WORK

Future work will entail updating this glossary as additional concepts prove useful.

REFERENCES

1. MIL-STD-1241, Optical Terms and Definitions, Standardization Division, Armed Forces Supply Support Center, Washington 25, D.C., Sept. 1960

2. Glossary of Terms Frequently used in Optics and Spectroscopy, Alva H. Bennett, American Optical Company (Retired). Published by The American Institute of Physics.

3. Monahan, T.I., and H. Korbel, ABD Thermal Radiation Effects Nomenclature, NML Project 5046-3, Part 35, Final Report, 18 March 1953.

4. Standard Terms and Symbols for Use on Project 41, Operation Blue Rock, Letter SMKOR, U. S. A. F. School of Aerospace Medicine, 20 Nov 1964

5. IES Lighting Handbook, Fourth Edition 1966, Illuminating Engineering Society

6. Vision Through The Atmosphere, W.E. Knowles Middleton, University of Toronto Press, 1952.

TABLE 1

SOURCE TERMS

Concept	Symbol	Unit	Definition
Radiant Power or Flux	P	watt	Rate of energy emission by a source
Luminous Power or Flux	F	lumen	
Radiant Energy	U([illegible])	watt-sec (joule)	Basic
Luminous Energy	U(L)	lumen-sec (talbot)	
Radiant Emittance	W	watt cm^{-2}	Power per unit source area
Luminous Emittance	L	lumen cm^{-2}	
Radiant Intensity	J	watt $ster^{-1}$	Power per unit solid angle emitted by a source
Luminous Intensity	I	lumen $ster^{-1}$ (candle)	
Radiance	R	watt $cm^{-2} ster^{-1}$	Power per unit solid angle per unit projected source area
Luminance	B	lumen $cm^{-2} ster^{-1}$	
Radiant Density	u	joule cm^{-3}	Energy per unit volume
Luminous Density	q	lumen-sec cm^{-3} (talbot cm^{-3})	

TABLE 2

MATERIAL TERMS

Concept	Symbol	Unit	Definition
Transmittance	t	numeric	Ratio of exiting to incident energy
Reflectance	r	numeric	Ratio of reflected to incident energy
Absorptance	A	numeric	Portion of energy not reflected or transmitted (1-r-t)
Emissivity	e	numeric	Ratio of energy emitted to that of a perfect blackbody emitter at the same temperature
Critical Radiant Exposure or Dose	Q_c	watt-sec $\cdot$ cm^{-2}	Radiant exposure for which an effect is produced in 50% of the samples
Safe Radiant Exposure or Dose	Q(safe)	watt-sec $\cdot$ cm^{-2}	Radiant exposure (maximum) which produces negligible effect

TABLE 3

RECEIVER TERMS

Concept	Symbol	Unit	Definition
Irradiance	H	watt·cm^{-2}	Power incident on a unit surface area
Illuminance	E	lumen·cm^{-2}	
Radiant Exposure	Q	joule·cm^{-2}	Energy incident on a unit surface area
Luminous Exposure	Q(L)	lumen-sec·cm^{-2}	
Radiant Dosage	Q_a	watt-sec·cm^{-3} watt-sec·gm^{-1}	Energy absorbed per cm^3 or gram

TABLE 4

STIMULUS RELATIONSHIP

BETWEEN PHOTOMETRIC AND RADIOMETRIC UNITS

The basic relationship is that the number of lumens = $680 \int_0^\infty P_\lambda V_\lambda d\lambda$ where V_λ is the visibility function

Radiometric	Terms and Units	Photometric	Terms and Units
Power or Flux	watt	Luminous Power or Flux	lumen
Energy	watt-sec	Luminous Energy	lumen-sec
Emittance	watt cm^{-2} (1)	Luminous Emittance	lumen cm^{-2} (1)
Intensity	watt $ster^{-1}$	Luminous Intensity	lumen $ster^{-1}$ (candle)
Radiance	watt cm^{-2} $ster^{-1}$ (1)	Luminance (Brightness)	lumen cm^{-2} $ster^{-1}$ (1)
Irradiance	watt cm^{-2} (2)	Illuminance	lumen cm^{-2} (2)
Radiant Exposure (Dose)	watt-sec cm^{-2} (2)	Luminous Exposure	lumen-sec cm^{-2} (2)

The luminosity or luminous efficiency of a source is the number of lumens per watt of the total spectrum.

(1) - Unit source area

(2) - Unit receiver area

TABLE 5

SPHERICAL SOURCE CHARACTERISTICS

Characteristics of an opaque uniform spherical lambertian source s, of diameter d, and Area A, radiating flux P, in a pulse varying with time t:

		P	W	J	R	Units
FLUX or POWER - Rate energy is given off by the source	P	P	WA, $W\pi d^2$	$4\pi J$	$R\pi A$, $R\pi^2 d^2$	cal sec^{-1} joule sec^{-1} watt
"TOTAL" ENERGY - Total energy in the pulse or in given period	U	$\int_{t_o}^{t_i} Pdt$				cal joule watt-sec
RADIANT EMITTANCE - FLUX or POWER per unit source area	W	$\frac{P}{A}$, $\frac{P}{\pi d^2}$	W	$4\pi J/A$, $4J/d^2$	πR	cal sec^{-1} cm^{-2} joule sec^{-1} cm^{-2} watt cm^{-2}
RADIANT INTENSITY - FLUX per solid angle	J	$P/4\pi$	$WA/4\pi$, $Wd^2/4$	J	$\pi d^2 R/4$	cal sec^{-1} $ster^{-1}$ joule sec^{-1} $ster^{-1}$ watt $ster^{-1}$
RADIANCE - FLUX per solid angle per unit projected source area	R	$P/\pi A$, $P/\pi^2 d^2$	W/π	$4J/\pi d^2$	R	cal sec^{-1} cm^{-2} $ster^{-1}$ joule sec^{-1} cm^{-2} $ster^{-1}$ watt cm^{-2} $ster^{-1}$

1 cal sec^{-1} = 4.187 joule sec^{-1} = 4.187 watts or
1 watt = 1 joule sec^{-1} = 0.239 cal sec^{-1}

TABLE 6

RADIOMETRIC RELATIONSHIPS AT THE EYE IN THE RETINAL BURN SITUATION AS RELATED TO SOURCE AND ATMOSPHERIC CHARACTERISTICS

IRRADIANCE HISTORY - rate energy is falling on a unit area of surface or plane	$H(t) = \frac{P(t)}{4\pi D^2} T_{atmos.}$	cal cm^{-2} sec^{-1} J cm^{-2} sec^{-1} watts cm^{-2}
RADIANT EXPOSURE (or DOSE) - accumulated energy per unit area for a pulse or for a given duration	$Q = \int_0^t H(t)dt$	cal cm^{-2} J cm^{-2} watts-sec cm^{-2}
RETINAL IRRADIANCE HISTORY -	$H_r(t) = H(t) \frac{d_p^2}{d_i^2} T_{eye} T_{filter}$	watts cm^{-2}
	$H_r(t) = R(t) \frac{\pi d_p^2}{4f_{eye}^2} T_{atmos.} T_{eye} T_{filter}$	
RETINAL RADIANT EXPOSURE (DOSE) -	$Q_r = \int_0^t H_r(t)dt$	watts-sec cm^{-2}
	$Q_r = \frac{\pi d_p^2}{4f_{eye}^2} T_{atmos.} T_{eye} T_{filter} \int R(t)dt$	

T is the transmission of the indicated medium
D is the distance from the source to the receiver
d_p is the pupil diameter
d_i is the retinal image diameter
f_{eye} is the focal length of the eye

TABLE 7

PLANE SURFACE SOURCE CHARACTERISTICS

The situation of an eye viewing a flat surface of area A normally, the surface radiating as a Lambertian plane through mediums having a transmission factor of T:

		F	L	I	B	Ep	
LUMINOUS FLUX	F	F	LA	πI	πBA	$\pi E_p D^2/T$	lumen
LUMINOUS EMITTANCE	L	F/A	L	$\pi I/A$	πB	$\pi E_p D^2/AT$	lumen cm^{-2}
LUMINOUS INTENSITY	I	F/π	LA/π	I	BA	$E_p D^2/T$	lumen $ster^{-1}$ (candle)
LUMINANCE	B	$F/\pi A$	L/π	I/A	B	$E_p D^2/AT$	lumen cm^{-2} $ster^{-1}$
ILLUMINANCE (PUPILLARY)	E_p	$FT/\pi D^2$	$LAT/\pi D^2$	IT/D^2	BAT/D^2	E_p	lumen cm^{-2}
ILLUMINANCE (RETINAL)	E_r	$\frac{F\, d_p^2\, T}{4A\, f_{eye}^2}$	$\frac{L\, d_p^2\, T}{4\, f_{eye}^2}$	$\frac{I\pi d_p^2\, T}{4A\, f_{eye}^2}$	$\frac{B\pi d_p^2\, T}{4\, f_{eye}^2}$	$\frac{E_p D^2 \pi d_p^2}{4A\, f_{eye}^2}$	lumen cm^{-2}

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)	2a. REPORT SECURITY CLASSIFICATION
U.S. Naval Applied Science Laboratory Flushing and Washington Avenues Brooklyn, New York 11251	UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

Glossary of Radiometric and Photometric Concepts Used in Retinal Burn and Flashblindness Research (Definitions, Symbols and Units)

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Progress Report

5. AUTHOR(S) (First name, middle initial, last name)

Willard Derksen
Neil Griff

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
23 December 1967	14	5

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO. 9400-12	Progress Report 18
c. DASA Subtask 03.001	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

10. DISTRIBUTION STATEMENT

This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Director, Defense Atomic Support Agency Department of Defense Washington, D.C. 20301

13. ABSTRACT

Radiometric and photometric concepts, symbols, units and definitions which are employed by the Naval Applied Science Laboratory in its retinal burn and flashblindness research are given.

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Radiometry						
Photometry						
Flashblindness						
Retinal Burns						
Symbols						
Units						
Definitions						

U.S. Naval Applied Science Laboratory.
Project 9400-12.
GLOSSARY OF RADIOMETRIC AND PHOTOMETRIC CONCEPTS USED IN RETINAL BURN AND FLASHBLINDNESS RESEARCH (DEFINITIONS, SYMBOLS AND UNITS) by W. Derksen and N. Griff. Progress Report 18. 23 Dec 1967. 14 p. illus. UNCLASSIFIED

Radiometric and photometric concepts, symbols, units and definitions which are employed by the Naval Applied Science Laboratory in its retinal burn and flashblindness research are given.

1. Radiometry - Glossaries
2. Photometry - Glossaries
I. Derksen, W.
II. Griff, N.
III. DASA Subtask 03.001

UNCLASSIFIED

U.S. Naval Applied Science Laboratory.
Project 9400-12.
GLOSSARY OF RADIOMETRIC AND PHOTOMETRIC CONCEPTS USED IN RETINAL BURN AND FLASHBLINDNESS RESEARCH (DEFINITIONS, SYMBOLS AND UNITS) by W. Derksen and N. Griff. Progress Report 18. 23 Dec 1967. 14 p. illus. UNCLASSIFIED

Radiometric and photometric concepts, symbols, units and definitions which are employed by the Naval Applied Science Laboratory in its retinal burn and flashblindness research are given.

1. Radiometry - Glossaries
2. Photometry - Glossaries
I. Derksen, W.
II. Griff, N.
III. DASA Subtask 03.001

UNCLASSIFIED

U.S. Naval Applied Science Laboratory.
Project 9400-12.
GLOSSARY OF RADIOMETRIC AND PHOTOMETRIC CONCEPTS USED IN RETINAL BURN AND FLASHBLINDNESS RESEARCH (DEFINITIONS, SYMBOLS AND UNITS) by W. Derksen and N. Griff. Progress Report 18. 23 Dec 1967. 14 p. illus. UNCLASSIFIED

Radiometric and photometric concepts, symbols, units and definitions which are employed by the Naval Applied Science Laboratory in its retinal burn and flashblindness research are given.

1. Radiometry - Glossaries
2. Photometry - Glossaries
I. Derksen, W.
II. Griff, N.
III. DASA Subtask 03.001

UNCLASSIFIED

U.S. Naval Applied Science Laboratory.
Project 9400-12.
GLOSSARY OF RADIOMETRIC AND PHOTOMETRIC CONCEPTS USED IN RETINAL BURN AND FLASHBLINDNESS RESEARCH (DEFINITIONS, SYMBOLS AND UNITS) by W. Darksen and N. Griff. Progress Report 18. 23 Dec 1967. 14 p. illus. UNCLASSIFIED

Radiometric and photometric concepts, symbols, units and definitions which are employed by the Naval Applied Science Laboratory in its retinal burn and flashblindness research are given.

1. Radiometry - Glossaries
2. Photometry - Glossaries
I. Derksen, W.
II. Griff, N.
III. DASA Subtask 03.C01

UNCLASSIFIED

REPORT ABSTRACT FORM
3ND-NASL-7700/1

3ND PPSO 13760